Appendix AS

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FOREST STRUCTURE AND PREY ABUNDANCE IN WINTER HABITAT OF NORTHERN GOSHAWKS

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Abstract: The U.S. Forest Service manages most southwestern ponderosa pine *(Pinus ponderosa)* for forest structures designed to increase abundance of prey for northern goshawks *(Accipiter gentilis).* The rationale for this strategy is a hypothesis that goshawk populations are limited by prey abundance. However, Beier and Drennan (1997) found that during the breeding season goshawks selected foraging sites not for higher prey abundance but for higher canopy closure, greater tree density, and greater density of trees >40.6 cm diameter at breast height (dbh). This finding supports the argument that prey availability (as determined by forest structure suited to goshawk maneuverability and hunting behavior) is more important than prey abundance. During winter, goshawks are under greater thermal stress, most avian prey have migrated, and most mammalian prey are hibernating. Under these conditions, foraging habitats may differ from those described for the breeding season. We radiotracked 13 adult goshawks (6 F, 7 M) during 2 winters (1994–1995 and 1995–1996) to investigate seasonal movements, winter diet, and selection of foraging habitat. Most females continued to use their breeding-season home ranges in ponderosa pine forest during winter. Meanwhile, most males moved into lower-elevation pinyon–juniper forest. In contrast to the high prey diversity noted during breeding season, wintering goshawks specialized on only 2 species of large-bodied prey (cottontails [*Sylvilagus* spp.] and Abert squirrel [*Sciurus aberti*]). Goshawks minimized energy expense and thermal exposure of flight by caching and feeding behavior. Sites where goshawks foraged had more medium-sized trees ($P = 0.06$) and denser canopy closure ($P = 0.06$) than nearby reference plots that lacked evidence of goshawk use. However, indices of prey abundance were nearly equal at used and reference plots. Although our findings do not support the underlying premise of the Forest Service management strategy for goshawks, we have no evidence that goshawks will experience lower survival or fecundity under such management. Regardless of the impact of management on goshawk fitness, we question the policy of managing most ponderosa pine habitat in the Southwest United States based on the needs of this species alone.

Nesting habitat for northern goshawks in Arizona and New Mexico, USA, is primarily ponderosa pine forests (Snyder and Snyder 1998). Changes to the structure of ponderosa pine forest due to timber harvest, fire suppression, and grazing prompted the U.S. Forest Service to designate northern goshawk as a sensitive species in the southwestern United States in 1982. Since that time, nest stands (≥8 ha) have been protected from timber harvest (Reynolds 1983). However, nest-stand protection alone was deemed insufficient after Crocker-Bedford (1990) documented a decline in goshawk reproduction after timber harvest occurred adjacent to protected nest stands. In response to that study and growing public concern over forest management, Reynolds et al. (1992) recommended managing 2,430 ha of forest surrounding each nest area for abundant populations of 14 primary prey species of goshawks. The U.S. Forest Service (1995, 1996) adopted these recommendations as policy not only for areas near known goshawk nests, but also for all ponderosa pine forest in Arizona and New Mexico (excluding those managed as Mexican spotted owl [*Strix occidentalis lucida*] habitat).

The Arizona Game and Fish Department (1993) and U.S. Fish and Wildlife Service (Spear 1993) argued that because accipiter hawks are adapted to forage in forested habitats, prey availability (as determined by forest structure) may be more important than prey abundance. Beier and Drennan (1997) found that goshawks apparently did not select foraging sites based on prey abundance during the breeding season, but instead hunted in areas that had relatively high canopy closure, high tree density, and high density of large (>40.6 cm dbh) trees.

In winter, cold temperatures and scarcity of prey may cause goshawks to select foraging habitat differently than during the breeding season, but selection may still be done largely on the

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basis of forest structure. No studies exist of winter habitat use for northern goshawks in North America and only 1 report of winter diet (Storer 1966). Although North American goshawks are partly migratory in the northern part of their range (Mueller and Berger 1967, Hoffman et al. 1990, Squires and Ruggiero 1995), we are unaware of published information on seasonal movements of goshawks that breed in southwestern ponderosa pine forests. We radiotagged 13 adult northern goshawks on their ponderosa pine forest breeding territories in northern Arizona to investigate (1) seasonal movements of goshawks; (2) winter diet: and (3) winter habitat selection by contrasting vegetation structure, prey abundance, and topography at winter foraging sites with nearby available forest.

STUDY AREA

We studied goshawks in the Coconino National Forest and nearby portions of the Kaibab National Forest in northern Arizona, USA (Fig. 1). These forests occur on a plateau with mostly flat topography broken by small cinder cones and ridges. Goshawks used areas with elevations ranging from approximately 1,900 to 2,600 m. During 1964–1993, Flagstaff (elevation 2,125 m) had a mean annual precipitation (rain and melted snowfall) of 540 mm and a mean annual temperature of 7.6 °C. Average daily low and high temperatures in January were –10 and 5 °C (National Oceanic and Atmospheric Administration 1993). The winter of 1994–1995 was near the mode for temperature and snowfall, but the winter of 1995–1996 was one of the warmest and driest winters with only 500 mm recorded snowfall.

These forests are dominated by ponderosa pine. At low elevations, ponderosa pine is co-dominant with pinyon pine (*Pinus edulis*). Alligator juniper (*Juniperus deppeana*), Utah juniper (*J. osteosperma*), and Gambel oak (*Quercus gambelii*) occur as understory trees. Ponderosa pine is less common in pinyon–juniper stands as elevation decreases. At higher elevations and on north-facing slopes, limber pine (*Pinus flexilis*) and Douglas-fir (*Pseudotsuga menziesii*) are co-dominant with ponderosa pine. Aspen (*Populus tremuloides*) occurs in the understory of mixed conifer forest or in small pure stands. Except in areas of dense pine or oak saplings, understories generally are open. Common understory species include lupine (*Lupinus* spp.). New Mexican locust (*Robinia neomexicana*), Arizona rose (*Rosa arizonica*), buckbrush (*Ceanothus fendleri*), snakeweed (*Gutierrezia*
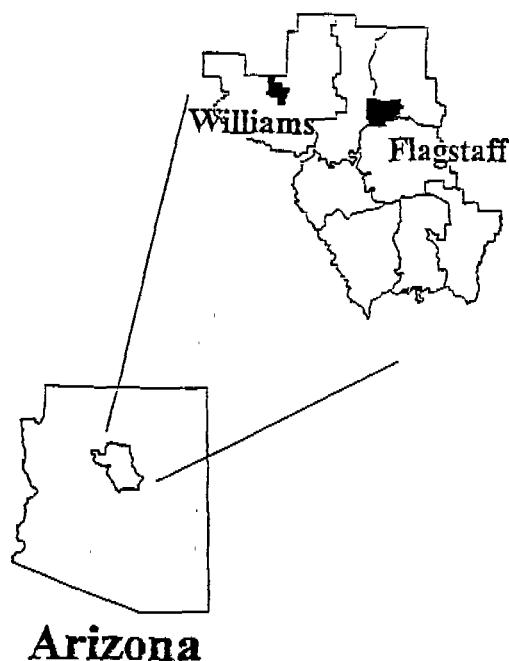
Arizona

Fig. 1. Map of Arizona with the study area on the Coconino National Forest and Kaibab National Forest enlarged.

spp.), Oregon grape (*Berberis repens*). showy aster (*Aster commutatus*), and grasses such as Arizona fescue (*Festuca arizonica*), mountain muhly (*Muhlenbergia montana*), and mutton bluegrass (*Poa fendleriana*). Plant names follow Kearney and Peebles (1964).

METHODS

Seasonal Movements

We captured adult goshawks at nest sites during 1994–1995 using dho-gaza traps (Bloom 1987) with a great horned owl (*Bubo virginianus*) as a lure. Each bird was fitted with a radiotransmitter (Telonics, Mesa, Arizona, USA) attached as a backpack harness made from 6-mm wide tubular Teflon ribbon. All transmitters contained a tip-switch that produced a slow pulse rate (1 pulse/1.3 sec) when oriented vertically (typical of a perching bird) and a faster pulse rate (1 pulse/0.7 sec) in a horizontal position (typical of flight and eating behavior). Transmitters weighed 28 g. about 3.3% and 2.5% of the average body mass of males and females. respectively.

We searched for each bird on a regular basis. usually once/week. to determine patterns of movement. From 5 December 1994 to 15 March

1995, ground radiotracking was used exclusively. In the second winter (10 Dec 1995–15 Mar 1996), hawks were radiotracked on the ground and on weekly flights in a Cessna 172, fixed-wing aircraft. For each bird, we calculated mean distance to the nest site and proportion of locations that were <5 km from the nest site. Mean values reported for males (n = 5) and females (n = 6) were calculated across birds, using each bird as a sample unit.

Winter Diet and Feeding Behavior

We used 2 methods to determine winter diet. The first method involved searching for pellets at night roosts by tracking birds after dusk (between 1800–2100) and flagging the general location. The following morning, we relocated the bird and night roost tree before dawn. We waited at least 30 min after first light, or until the goshawk flew from its perch, before searching for pellets under the roost tree.

The second method involved approaching goshawks when their telemetry signal indicated that they had made a kill or were consuming prey. The diagnostic signal of a feeding goshawk was characterized by a fast pulse signal that occasionally changed to a slow pulse for intervals <10 sec. This pattern corresponded to the goshawk bending forward into a horizontal position and plucking its prey. The short intervals of slow pulse signals corresponded to plucking momentum sending the bird into an upright position. Longer intervals of slow pulse signals were often associated with the goshawk's awareness of our presence. After observing the bird for >30 min and carefully determining its location, we approached the goshawk to identify the prey species. Most birds were reluctant to leave their prey, but they were unable to fly >50 m with large items (e.g., cottontails). Where possible, we attempted to avoid excessive disturbance to feeding goshawks by identifying prey from a remote location using binoculars.

Microhabitat Selection

To obtain accurate locations on foraging goshawks, teams of 2 researchers tracked individual birds for periods of 1–6 hr between 5 December 1994 to 15 March 1995 and 10 December 1995 to 15 March 1996. Using flight and perch durations reported by Kenward (1982), Widén (1984), and Kennedy (1990), we interpreted changes in pulse rates as foraging behavior when periods of fast pulse rate <3 min alternated with periods of slow pulse rate <12 min. Longer periods of a fast

pulse rate indicated birds that were either bent over feeding, flying long distances, or dead. Longer periods of slow pulse rate indicated perched birds. To minimize disturbance, surveyors stayed together until they were <200 m from an apparently foraging bird then separated until their azimuths approximated a 90° angle. Observers walked directly toward the apparent location of the bird until the signal volume suggested that they were approximately 100 m from the goshawk. From this distance, observers confirmed their bearing and quietly approached while visually scanning for the bird and counting the paced length of the bearing line. If the bearing line exceeded 150 m and the goshawk was not observed flushing, the point was rejected and the bird was abandoned for >4 hr. Our intention was to avoid locating used plots in habitats where goshawks flew to avoid approaching surveyors. We observed a goshawk with prey (usually identified to species) at 59% (26 of 44) of the locations that served as centers of used plots. Earlier trials (Beier and Drennan 1997) indicated a mean error of 22 m (SE = 3.4) for the walk-in protocol.

We used only these precise walk-in locations as centers of used plots. For each used plot, we established a paired reference plot in forested habitat centered in a random direction approximately 500 m from each used plot center and >200 m from any previous winter location for that bird. This paired design is appropriate for determining microhabitat selection and has more statistical power than strict random sampling because it minimizes the influence of variation sources not related to habitat selection (Ratti and Garton 1994:15–16).

Prey Abundance

We indexed prey abundance at each used plot and its paired reference plot on a single day, 1–4 days after obtaining the goshawk location. We indexed abundance of avian prey by counting all birds heard or seen within 3 min (Ralph et al. 1993) at 4 points (plot center and at 100 m from the center at 60, 120, and 240°) and 3 counts/point (immediately following establishment of the plot, at dusk that evening, and at dawn the following morning) using 50-m fixed-radius plots.

On the second and third bird counts, we alternated the survey order, counting the reference plot before the used plot. The time between sampling used and reference plots was never >4 hr and was typically <1 hr. For analysis, we grouped avian prey into 3 classes based on body mass (Ter-

res 1991). Large birds (75–145 g) included American robin (*Turdus migratorius*), Steller's jay (*Cyanocitta stelleri*). northern flicker (*Colaptes auratus*). mourning dove (*Zenaida macroura*). Lewis's woodpecker (*Melanerpes lewis*), and Clark's nutcracker (*Nucifraga columbiana*) Medium birds (30–62 g) included hairy woodpecker (*Picoides villosus*) western bluebird (*Sialia mexicana*), and evening grosbeak (*Coccothrausies vespertinus*). Small birds (11–19 g) included pine siskin (*Carduelis pinus*), pygmy nuthatch (*Sitta pygmaea*), dark-eyed junco (*Junco hyemalis*), and western wood-pewee (*Contopus sordidulus*).

We indexed mammalian abundance (e.g., Abert squirrels and lagomorphs) by counting tracks, sign, and visual observations along a 1,200 m transect (5 traverses of 200 m each and 4 connecting segments of 50 m each) in a 200 × 200 m square in each plot. Tracks were more visible on snow leading to greater detection rates than open ground. However, snow conditions did not bias results because they were always similar on paired plots.

Forest Structure

We characterized habitat structure on 1.77 ha (75 m radius) plots, using the same plot centers as prey surveys by sampling along 6 radii (0, 60, 120, 180, 240, 300°) to give greater weight to vegetation near the plot center (i.e., the goshawk location on used plots). Trees within 1 m of each radius were counted and assigned to 1 of 3 diameter classes. Canopy closure (using vertical sighting tubes) and ground cover were measured by point intercept at 91 points (plot center and every 5 m along each radius), and number of shrubs and saplings intercepted by the radii were counted. We tallied all large (≥30.5 cm dbh) snags and all large downed logs (≥30.5 cm in diameter at midpoint and ≥2.4 m long) on a 50 × 50 m plot centered on the foraging location (for used plots) or the plot center for reference plots. The smaller plot size for snags and downed logs was selected to obtain a reliable estimate for the overall plot and avoid excessive sampling time for minimal gain in accuracy. We also recorded slope (%), aspect (to nearest multiple of 45°), and topographic position (flat, midslope, ridge, or drainage bottom) at plot center.

Data Analysis

We used compositional analysis (Aebischer et al. 1993) to test for differences between used and reference plots in aspect, topographic position.

and percent ground cover. For all other variables. we computed the difference in prey-abundance indices and vegetation parameters between each used plot and its paired reference plot. We then computed the average difference in variables for each goshawk. Finally, using the bird as the sampling unit, we used paired *t*-tests to test whether the mean difference across birds varied from zero. Before statistical analyses, we applied a square-root transformation to all counts and an arcsine square-root transformation to canopy-closure percentages.

RESULTS

Seasonal Movements

We radiotracked 6 adult goshawks during winter 1994–1995 and 7 adult goshawks during winter 1995–1996 (Table 1). Five or more radiolocations were recorded for 11 of these birds (1 transmitter failed and 1 bird traveled >25 km from its nest site for most of the winter). Excluding 1 male, goshawks were winter residents and did not undertake long distance migrations. Females were relocated <5 km from their nest tree on 72% of locations, and males were relocated <5 km from the nest on 45% of locations. Female relocations averaged 6.17 km (SE= 1.18) from the nest tree and males averaged 7.44 km (SE = 0.75).

All 6 females were relocated in ponderosa pine forest throughout the winter. Four females were relocated exclusively in ponderosa pine, and 2 were relocated in both ponderosa pine and pinyon–juniper forest (Table 1). Only 1 male was consistently relocated in ponderosa pine forest throughout the winter. The remaining 4 male goshawks were relocated in pinyon–juniper forests or in the ecotone between ponderosa pine and pinyon–juniper forest (Table 1).

Winter Diet and Feeding Behavior

We were unable to locate any pellets or prey remains under night roost trees used by 5 goshawks (on a total of 15 occasions) even with excellent search conditions (e.g., fresh snowfall). Goshawks did not roost in the same area on successive nights unless they had recently captured a large prey item. On 3 separate occasions, birds roosted near cottontail carcasses and consumed the prey over 2–3 days. Carcasses typically were located in dense cover on the ground, often under the lower limbs of juniper trees. Monitoring these feeding sites revealed that

Table 1. Prey killed and gross winter movements for 13 goshawks during the winters of 1994 (Dec 1994–Mar 1995) and 1995 (Dec 1995–Mar 1996) on the Coconino and Kaibab National Forests, Arizona, USA. We obtained no microhabitat data on the Fort Valley male and the White Horse male; there were 4 pairs of microhabitat plots for each of the other goshawks.

Goshawk (territory and sex)	Winter	Known prey killed[a]	No. of relocations	Mean distance from nest (km)	% of locations <5 km from nest	Primary habitat types[b]
					Winter movements	
Horseshoe F	1994	0	6	4.90	66	PP
Mars Hill F	1994	0	9	2.62	89	PP
Walker F	1994	2 Abert squirrels	10	3.25	80	PP
Fort Valley F	1995	4 Abert squirrels	23	4.21	87	PP
Devil Dog F	1995	3 cottontails	15	9.94	73	PP; PJ
Volunteer F	1995	4 cottontails	16	9.76	38	PP; PJ and; several visits to Sycamore Canyon (pine-oak; ~8 km)
Volunteer M	1995	4 cottontails	13	4.78	69	PP
Walker M	1994	0	7	5.11	71	PP; PJ
Sitgreaves M	1995	3 cottontails	17	5.59	52	E; PJ
Porkchop M	1994	3 cottontails	5	7.59	20	PJ
Elk Spring M	1995	4 cottontails	15	12.87	13	PJ
Fort Valley M	1995	0	7			Unknown (moved >25 km from nest for ~3 month period Nov 21–Feb 16)
Whitehorse M	1994	0	1			Unknown (transmitter failed)

[a] For each animal at least 7 days elapsed between observations of fresh kills (except 1 interval of 4 days for Fort Valley female).
[b] PP = ponderosa pine, PJ = pinyon-juniper, E = ecotone between PP and PJ.

goshawks spent most of their time within 50 m of the carcass until it was consumed. Because most nights were below freezing, feeding did not occur until late morning or afternoon when carcasses thawed.

Importance of Prey Abundance and Vegetation Structure in Habitat Selection

We sampled 4 pairs of plots for each of 11 goshawks ($n = 5$ in 1994–1995; $n = 6$ in 1995–1996). Used plots had more medium-sized trees ($P = 0.06$) and denser canopy closure ($P = 0.06$) than reference plots (Table 2). Used plots averaged 50% canopy closure and 230 medium-sized trees/ha, whereas reference plots averaged 44% canopy closure and 192 medium-sized trees/ha. Indices of prey abundance were nearly identical between used plots and reference plots (Table 3).

DISCUSSION

Seasonal Movements

Throughout 2 winters, most goshawks did not undertake long-distance migrations and were usually relocated <12 km from their nest stand. Only 1 of 13 (7.6%) goshawks moved >25 km away from his nest site during winter, unlike goshawk populations in more northern latitudes that migrate, usually in response to prey declines (Mueller et al. 1977, Doyle and Smith 1994). In a study in south-central Wyoming, 4 goshawks were migratory and completely abandoned their breeding-season range during winter (Squires and Ruggiero 1995). Resident status of goshawks in our study area suggests that other goshawk populations located in central and southern Arizona may also be year-round residents at breeding territories.

Goshawks were frequently relocated in ponderosa pine forest, often within their nest stands. On 2 occasions, we elicited defensive behavior from female goshawks while present in the nest stand. We speculate that female goshawks have greater winter fidelity to the nest stand because of their larger size and greater ability to defend a territory from large raptors (including other goshawks). Movements of most male goshawks toward pinyon–juniper forests may be in response to reduced diversity and abundance of prey in ponderosa pine habitats in winter (due to migration and hibernation of most prey species), as well as competition from females. Although prey abundance was not a factor in selection of foraging sites within goshawk home ranges, it probably is an important component of goshawk habitat at the landscape level. During 1992–1994, none of 26 radiotagged goshawks used pinyon–juniper habitat in the breeding season (Beier and Drennan 1997; P. Beier, Northern Arizona University, unpublished data).

Table 2. Vegetation and physical characteristics on 44 (1.77 ha) plots used by 11 adult goshawks (6 F, 5 M) in northern Arizona, USA, Dec 1994–Mar 1995 and Dec 1995–Mar 1996, and 44 paired reference plots.

Characteristic	Used plots		Reference plots		Difference	
	Mean	SD	Mean	SD	Used–reference	P
Aspect (% of plots)						0.93[a]
N and NE	18	12	20	15	−2	
E and SE	9	17	5	10	+4	
S and SW	23	21	23	18	0	
W and NW	34	23	36	21	−2	
Flat	16	20	16	17	0	
Topographic position (% of plots)					0.65a	
Ridgetop	0	0	0	0	0	
Midslope	61	26	55	29	+6	
Canyon bottom	16	20	18	25	−2	
Flat	16	16	20	24	−4	
% ground cover						0.55[a]
Grasses and forbs	3.3	2.6	7.2	6.1	−3.9	
Bare ground, incl. roads	7.5	11.5	7.6	13.5	−0.1	
Litter	44.7	26.7	40	28	+4.7	
Downed wood or stump	1.6	1.3	1.6	1.4	−0.02	
Rock (>15 cm long axis)	3.9	1.9	4.8	4.5	−0.9	
% slope	10.5	9.2	8.7	7.1	+1.9	0.57[b]
Shrubs & saplings intercepted						
by 430-m transect	20	37	35	66	−14.5	0.13[b]
% canopy closure	50	6.7	44	12.2	+6.2	0.06[b]
Large snags/ha	1.1	1.0	1.1	0.8	+0.1	0.92[b]
Large logs/ha	4.0	2.8	4.0	4.0	0	0.58[b]
Trees/ha:						
Total trees (>10 cm dbh)	704	282	696	391	+8.5	0.94[b]
0–20.3 cm dbh	1,178	1,259	1,243	1,389	−65	0.18[b]
20.4–40.6 cm dbh	230	70	192	84	+38	0.06[b]
>40.6 cm dbh	32	18	29	16	+3.2	<0.15[b]

[a] Compositional analysis using MANOVA of log-ratio-transformed percents (4, 7 df for aspect and ground cover; 3, 8 df for topographic position).

[b] Two-tailed paired-sample *t*-test (10 df) comparing mean difference (across 11 birds) to zero.

Winter Diet and Feeding Behavior

Direct observation of prey animals was the most successful method of determining diet. Some goshawks do not eject pellets at night roost sites despite spending >12 hr perched in a single location. We identified 2–4 freshly killed prey items ($n = 27$) for each of 8 adult goshawks by radiotelemetry (Table 1). Abert squirrels ($n = 6$) and cottontails ($n = 21$) were the only prey species documented. No individual goshawk took both Abert squirrels and cottontails, suggesting that each specialized on a single, large-bodied prey species during winter. The association between individual goshawks and these prey species was not due to chance (exact binomial probability, $P < 0.00001$). Individuals that wintered in pinyon–juniper habitats (including ecotones) were found only with cottontails, whereas goshawks wintering in ponderosa pine took either Abert squirrel or cottontail, but not both.

Published lists of species observed in breeding-season diets of goshawks nesting in western North America include 21 mammal and 45 bird species (Schnell 1958, Bloom et al. 1986 Kennedy 1990, Boal and Mannan 1994, Bull and Hohmann 1994, Reynolds et al. 1994). During winter, mantled ground squirrels (*Spermophilus lateralis*), which were the primary prey item on the nearby Kaibab plateau during the breeding season (Boal and Mannan 1994), are hibernating (Hoffmeister 1986), and most bird species have migrated. We observed only 2 prey species, suggesting that diet breadth is extremely low for goshawks in winter. Although smaller prey items may have been consumed, the biomass contribution of any undetected smaller prey would represent only a small fraction of the overall diet. Individual specialization for large-bodied prey probably is influenced by habitat selection, with goshawks wintering in ponderosa pine more likely to specialize in Abert squirrel and goshawks wintering in pinyon–juniper more likely to consume cottontails. Such reliance on a single prey species may increase susceptibility of goshawks to

Table 3. Differences in counts of prey or prey sign between used and reference plots for 11 goshawks sampled in northern Arizona, USA, during winter months of 1994–1996. Significance level is that of a 2-tailed *t*-test of the hypothesis that the mean difference (used minus reference) across 11 birds is zero.

Prey group	Used plots		Reference plots		Difference	P
	Mean	SD	Mean	SD		
Abert squirrel (track counts)	5.1	6.6	5.3	6.7	−0.2	0.77
Abert squirrel (observations)	3.5	7.7	3.9	8.2	−0.4	0.53
Lagomorph (track counts)	0.16	0.26	0.09	0.17	0.07	0.28
Lagomorph (observations)	0.11	0.17	0.09	0.23	0.02	0.72
Large birds	4.4	4.3	4.3	5.3	0.1	0.88
Medium birds	3.1	3.8	3.1	3.4	0	0.98
Small birds	31.5	16.3	32.1	11.7	−0.6	0.81

fluctuations in specific prey populations (Newton 1979). Cottontail and Abert squirrel populations may fluctuate annually (Hall 1981) and thus influence goshawk populations more than previously recognized. Further study on population dynamics of these prey species would provide a better understanding of factors affecting goshawk ecology.

Our study is the first to report winter caching behavior of goshawks. The larger prey size probably prohibited removal of prey items to safer refuges used in the breeding season (Schnell 1958, Zachel 1985). Larger prey items also contributed to reduced flight activity by goshawks because they spent most of their time perched near the cache. This behavior probably minimizes loss of carcasses to scavengers and energy expense and thermal exposure of more frequent hunting for smaller prey. We found it interesting that all male goshawks consumed cottontails exclusively. Based on their smaller size (850 g) compared to females (1,100 g), males would be expected to specialize in Abert squirrel, the smaller of the 2 available prey species. In other studies that compared goshawk diet to other Accipiter species, mean prey size was correlated with the mean body mass of each species (Opdam 1975, Reynolds and Meslow 1984).

Importance of Prey Abundance and Vegetation Structure in Habitat Selection

As suggested by Beier and Drennan (1997), habitat selection possibly is a 2-tiered process. At the level of locating a home range within a large landscape (second-order selection, sensu Johnson 1980), goshawks probably do respond to prey abundance. Our detected expansion and shift of wintering goshawks into pinyon–juniper habitats where they have access to a more-abundant population of large-bodied prey is consistent with Beier and Drennan (1997).

However, at the level of selecting a foraging site within a home range and habitat type (third-order selection), goshawks select sites for moderately dense, mature forests where they can use their maneuverability to capture prey (Mavrogordato 1973:160, Snyder and Snyder 1998). This pattern is consistent with habitat selection during the breeding season, where goshawks selected foraging sites based on forest structure rather than prey abundance (Beier and Drennan 1997) and further supports the hypothesis that goshawks are habitat specialists even during winter.

MANAGEMENT IMPLICATIONS

If managers consider winter ecology of northern goshawks, 2 prey species (cottontails in pinyon–juniper habitats and Abert squirrels in ponderosa pine habitats) assume larger importance than previously reported. Because ponderosa pine forest is considered marginal cottontail habitat (Hoffmeister 1986), pinyon–juniper forest may be a critical component of year-round goshawk habitat in this region. Fidelity to nest sites in ponderosa pine forest during winter underscores the importance protecting nest stands and Abert squirrels as year-round prey.

We believe that the U.S. Forest Service guidelines (Reynolds et al. 1992) of managing forests to support abundant populations of 14 primary goshawk prey species are not justified in terms of how goshawks select habitat. These guidelines assume that prey availability and habitat structure are equally important factors of goshawk foraging habitat (Reynolds et al. 1992:4). In fact, our research suggests that habitat structure is more important than prey availability. Although the guidelines recommend maintaining more open forests with less canopy closure and lower tree density in goshawk foraging areas (40–60%), this should not negatively affect goshawks. If future studies document a decline in goshawk repro-

duction and survival due to a more open forest canopy and lower tree density in foraging areas. managers should reevaluate desired future conditions for forest structure. Crocker-Bedford (1990) clearly documented a decline in goshawk reproduction as a result of intense timber harvest during the 1980s. but no evidence exists that the species. or the southwestern population in particular, is threatened (Braun et al. 1996. Kennedy 1997). We believe that the guidelines may improve overall forest health in Arizona and New Mexico, but agree with Braun et al. (1996:11) that "management of southwestern forests must involve an ecosystem/landscape approach and should not be narrowly focused on 1 species."

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